

MULTIBEAM SCANNING OPTICAL APPARATUS

AND

COLOR IMAGE-FORMING APPARATUS

5 BACKGROUND OF THE INVENTION

Field of the Invention

10 This invention relates to a multibeam scanning optical apparatus and also to a color image-forming apparatus. A multibeam scanning optical apparatus is an apparatus adapted to optically scan the surface of an object by means of a plurality of light beams that are emitted from one or more than one light sources, deflected by an optical deflector and transmitted by way of a scanning optical system having an $f\theta$ characteristic. A color image-forming apparatus is an apparatus adapted to record image information obtained by scanning the surface of an image carrier by means of deflected light. Such apparatus find applications in the field of laser beam printers (LBPs) and digital copying machines having a feature of carrying out a color electrophotography process.

Related Background Art

25 In conventional scanning optical apparatus to be used for image-forming apparatus such as laser beam printers and digital copying machines, the light beam emitted from a light source and optically modulated according to the image signal applied to it is

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scanned by way of a scanning optical element having an
f θ characteristic (f θ lens) 86 so that the surface 88
of the photosensitive drum is optically scanned in the
direction indicated by arrow 88a (main-scanning
5 direction) to record the scanned image as the light
deflector 85 is driven to rotate in the sense of arrow
85a.

In order to accurately control the starting point
of the operation of drawing the image for the scanning
10 optical apparatus, the light beam deflected by the
light deflector 85 is partly taken out and entered to
beam detector (BD) sensor 92 by way of the scanning
optical element 86, a beam detector (BD) mirror 95 and
a slit 91 immediately prior to the start of writing the
15 image signal. Then, the output signal of the beam
detector (BD) sensor 92 is used to regulate the timing
and the spot at which the operation of drawing the
image on the surface of the photosensitive drum is
started.

20 In recent years, as a result of technological
development in the field of image forming apparatus
involving the use of an electrophotography process
particularly in terms of high speed and high
resolution, there is an ever-increasing demand for
25 multibeam scanning optical apparatus comprising a
multibeam laser device having a plurality of light
emitting sections and scanning optical apparatus of the

type employing a plurality of scanning optical apparatus as so many units in order to realize high speed color image formation as shown in FIG. 2 that illustrates a tandem type color image forming apparatus where a plurality of scanning optical apparatus are operated simultaneously for different colors in order to record image information on respective photosensitive drums as well as hybrid type color image forming apparatus realized by combining apparatus of the above identified types. In FIG. 2, reference numerals 111, 112, 113 and 114 denote respective scanning optical apparatus and reference numerals 121, 122, 123 and 124 denote respective photosensitive drums operating as so many image carriers, whereas reference numerals 131, 132, 133 and 134 denote respective developing units and reference numeral 141 denotes a conveyor belt.

Since the manufacturing cost of such scanning optical apparatus is vital, the scanning optical element (f θ lens) is typically prepared by plastic molding without the process of compensating, if any, the chromatic aberration of magnification.

However, in the case of a multibeam scanning optical apparatus adapted to form a final image by means of light beams of a multibeam laser having a plurality of light emitting sections, the plurality of light beams can show discrepancies in terms of

magnification to consequently degrade the quality of the produced image due to various factors including those listed below:

- (1) variances of the initial wavelengths of a plurality of light beams emitted from the multibeam laser;
- (2) variances of the wavelength of the plurality of light beams caused by mode hopping of the multibeam laser that is attributable to environmental changes; and
- (3) fluctuations in the refractive index of the plastic lens also attributable to environmental changes.

In FIG. 1, there are also shown the image region of the known scanning optical apparatus and the displacements of the focussing positions of the light beams as detected at the start of drawing the image when the wavelength of the light source of laser B (as observed by the laser beam emitted from the light source) is modified relative to the wavelength of the light source of the laser A. Note that, while only the focussing points of laser A and laser B are indicated by A and B respectively in FIG. 1, there are actually more focussing points that are not illustrated in FIG. 1.

In an actual image, the displacements of focussing positions on the surface being scanned due to variations of magnification (wavelength) do not give rise to any jittering along the left edge of the image

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but they do along the right edge of the image as shown
in FIG. 3 to consequently degrade the recorded image.
This is because the timing and the spot at which the
operation of drawing the image on the surface of the
5 photosensitive drum is started are regulated
(synchronized) at the side of starting the scanning
operation as pointed out above. More specifically,
referring to FIG. 1, the detection light beam to be
detected by the BD sensor 92 of the known scanning
10 optical apparatus strikes aslant the $f\theta$ lens 86 shared
with the light beams for scanning the surface to be
scanned and, if the wavelength of the laser beam
emitted from the laser A differs from that of the light
beam emitted from the laser B, they produce a relative
15 deviation of the focussing positions equal to that of
the starting points of scanning the surface to be
scanned. Thus, the starting points of scanning of the
light beams can be made to agree with each other by
detecting a part of each of the light beams and so
20 controlling the scanning timing of the beam as to
correct the relative deviation of the focussing
positions due to the difference of the wavelengths on
the basis of the signals obtained by detecting the
laser beams. However, it will be appreciated that, as
25 a result, a remarkable jittering phenomenon can appear
at the terminating points of scanning.

A similar problem arises in the scanning optical

apparatus of tandem type color image forming apparatus.
More specifically, when magnification discrepancies
arises among a number of scanning optical apparatus, a
relative deviation of registration occurs over the
5 range from the center toward the right edge of the
image as shown in FIG. 4 among different colors to
consequently degrade the produced image. While FIG. 4
shows a relative deviation of registration between B
(black) and C (cyan), a similar deviation can occur
10 among any different colors.

SUMMARY OF THE INVENTION

In view of the above identified circumstances, it
is therefore the first object of the present invention
15 to provide a multibeam scanning optical apparatus that
can effectively reduce jittering that can arise due to
variations (deviations) of magnification among a
plurality of light beams attributable to the difference
of initial wavelength (wavelength deviation) among the
20 plurality of light beams emitted from so many light
emitting sections and environmental changes even when a
molded plastic lens is used without being subjected to
a process of correcting the chromatic aberration of
magnification.

25 The second object of the present invention is to
provide a color image forming apparatus having a simple
configuration and free from the above pointed out

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a light source having a plurality of light beam
emitting sections;

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a scanning optical system for focussing said plurality of light beams deflected by said light deflector on a surface to be scanned; and

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beams have respective wavelengths that are different from each other.

According to the invention, there is also provided a multibeam scanning optical apparatus comprising:

5 a light source having a plurality of light beam emitting sections;

a light deflector for deflecting a plurality of light beams emitted respectively from said plurality of light beam emitting sections of said light source;

10 a scanning optical system for focussing said plurality of light beams deflected by said light deflector on a surface to be scanned;

a photodetector for controlling the timing of the start of scanning of said plurality of light beams by detecting a part of at least one of said plurality of light beams deflected by said light deflector as detection light beam; and

15 a detection optical element for converging said detection light beam and leading it to said photodetector;

20 said detection optical element having its optical plane arranged orthogonally relative to said detection light beam.

According to the invention, the above second object is achieved by providing a color image forming apparatus comprising:

a plurality of scanning optical apparatus, each

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having light source, a light deflector for deflecting a light beam emitted from said source, a scanning optical system for focussing the light beam deflected by said light deflector on a surface to be scanned and a

5 photodetector for controlling the timing of the start of scanning of said light beam by detecting a part of said light beam deflected by said light deflector as detection light beam, said photodetector and the center of the scanning width in the main-scanning direction on
10 the surface to be scanned being held optically equivalent; and

a plurality of image carriers arranged respectively on the surfaces to be scanned of said scanning optical apparatus for forming images with
15 respective different colors.

According to the invention, there is also provided a color image forming apparatus comprising:

a plurality of scanning optical apparatus, each having light source, a light deflector for deflecting a
20 light beam emitted from said source, a scanning optical system for focussing the light beam deflected by said light deflector on a surface to be scanned, a photodetector for controlling the timing of the start of scanning of said light beam by detecting a part of
25 said light beam deflected by said light deflector as detection light beam and a detection optical element for converging said detection light beam and leading it

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to said photodetector, said detecting optical element having its optical plane arranged orthogonally relative to said detection light beam; and

a plurality of image carriers arranged
5 respectively on the surfaces to be scanned of said scanning optical apparatus for forming images with respective different colors.

When the plurality of light beams show respective wavelengths that are different from each other in a
10 multibeam optical apparatus according to the invention, the timing of the start of scanning is so controlled as to make the centers of the scanning areas of said light beams agree with each other on the surface to be scanned simply by controlling the timing of scanning in
15 the main-scanning direction at or near the center of the scanning width in the main-scanning direction on the surface to be scanned by means of the photodetector (BD) sensor. This means that the photodetector and the center of the scanning width in the main-scanning
20 direction on the surface to be scanned are held optically equivalent. Similarly, in each of the scanning optical apparatus of a color image forming apparatus according to the invention, the timing of the start of scanning is so controlled as to make the
25 centers of the scanning areas of said light beams agree with each other on the surface to be scanned simply by controlling the timing of scanning in the main-scanning

direction at or near the center of the scanning width in the main-scanning direction on the surface to be scanned by means of the photodetector (BD) sensor.

5 The photodetector and the center of the scanning width in the main-scanning direction on the surface to be scanned can be held optically equivalent by so arranging the detecting optical element for focussing the detection light beam and leading it to the photodetector (BD) sensor as to have its optical plane
10 arranged orthogonally relative to said detection light beam. This is because the main light beam of the flux of light striking the center of the scanning width in the main-scanning direction generally agrees with the optical axis of the scanning optical system ($f\theta$ lens)
15 and hence this light beam and the light beam entering the photodetector (BD) sensor are made to optically equivalent.

For the purpose of the invention, the expression that "the detecting optical element having its optical
20 plane arranged orthogonally relative to the detection light beam" means that the main light beam of the flux of light as detected by the photodetector (BD) sensor substantially agrees with the optical axis of the detecting optical element. The expression "as detected
25 by the photodetector" is used because the light beam entering the photodetector is used for scanning and therefore the main light beam of the flux of light does

not always agree with the optical axis of the detecting optical element. In other words, there exists a state where the main light beam of the flux of light being used for scanning can agree with optical axis of the detecting optical element.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a principal portion of a known scanning optical apparatus.

FIG. 2 is a schematic illustration of a principal portion of a known tandem type color image forming apparatus.

FIG. 3 is a schematic illustration of a surface being scanned by a known scanning optical apparatus, showing some focussing positions.

FIG. 4 is a schematic illustration of a surface being scanned by a known tandem type color image forming apparatus, showing some focussing positions.

FIG. 5 is a schematic cross sectional view of a principal portion of the first embodiment of multibeam scanning optical apparatus according to the invention taken along the main-scanning direction thereof.

FIG. 6 is a schematic illustration of a surface being scanned by the first embodiment of multibeam scanning optical apparatus, showing some focussing positions.

FIG. 7 is a schematic cross sectional view of a

principal portion of the second embodiment of the invention, which is a color image forming apparatus, taken along the main-scanning direction thereof.

FIG. 8 is a schematic illustration of a surface
5 being scanned by the second embodiment of color image forming apparatus, showing some focussing positions.

FIG. 9 is a schematic cross sectional view of a
principal portion of the third embodiment of the
invention, which is also a multibeam scanning optical
10 apparatus, taken along the main-scanning direction thereof.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now, the present invention will be described in
15 greater detail by referring to the accompanying drawings that illustrate preferred embodiments of the invention.

[Embodiment 1]

FIG. 5 is a schematic cross sectional view of a
20 principal portion of the first embodiment of multibeam scanning optical apparatus according to the invention taken along the main-scanning direction thereof.

In FIG. 5, reference numeral 1 denotes a light
source comprising a multi-semiconductor laser
25 (multibeam laser) having a plurality of light emitting sections (laser A and laser B in this embodiment) for emitting a plurality of light beams that are optically

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modulated independently.

Reference numeral 2 denotes a collimator lens operating as first optical element for collimating the plurality of light beams emitted from the light source 1. Reference numeral 3 denotes a diaphragm 3 for restricting the quantity of light passing therethrough. Reference numeral 4 denotes a cylindrical lens (cylinder lens) operating as second optical element and showing refractive power of a predetermined level only in the sub-scanning direction. It focusses, in the direction of the sub-scanning plane, the plurality of light beams passing through the diaphragm 3 on the deflection plane (reflection plane) 5a of optical deflector 5, which will be described below, as a linear image.

Reference numeral 5 denotes an optical deflector that may be a rotary polygon mirror driven to rotate at a predetermined rate in the sense indicated by arrow 5a in FIG. 5 by a drive means (not shown) such as an electric motor.

Reference numeral 6 denotes a scanning optical element operating as third optical element showing a $f\theta$ characteristic and comprising a refraction optical element 61 and a diffraction optical element 62. The refraction optical element 61 consists of a single plastic toric lens whose optical power differs between the main-scanning direction and the sub-scanning

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direction. The diffraction optical element 62 consists of an oblong plastic diffraction element whose optical power differs between the main-scanning direction and the sub-scanning direction. While the oblong
5 diffraction element 62 of this embodiment is made of plastic and formed by injection molding, it may alternatively be a diffraction grating formed as replica on a glass substrate.

In this embodiment, the toric lens 61 is arranged
10 at the side of the polygon mirror 5 relative to the middle point of the axis of rotation of the polygon mirror 5 and the surface to be scanned 8, whereas the diffraction optical element 62 is arranged at the side of the surface to be scanned relative to the middle
15 point. Each of the above listed optical elements has optical power that differs between the main-scanning direction and the sub-scanning direction and operates to focus the deflected light beam from the polygon mirror 5 on the surface to be scanned and correct the
20 inclination of the deflection plane of the polygon mirror. When the multibeam scanning optical apparatus is applied to an electronic photograph printer, the surface to be scanned 8 refers to the surface of the photosensitive drum of the printer. Therefore,
25 reference numeral 8 refers to the surface of a photosensitive drum hereinafter.

Reference numeral 7 denotes a synchronism

detecting optical element comprising an anamorphic lens
made of plastic and showing optical power that differs
between the main-scanning direction and the sub-
scanning direction. In this embodiment, the surfaces
5 of the anamorphic lens 7 is arranged substantially
orthogonally relative to the plurality of light beams
from the polygon mirror 5 (synchronism detection light
beams) 73 for controlling the timing of scanning the
surface of the photosensitive drum 8 in the main-
10 scanning direction (synchronizing timing) and adapted
to focus the synchronism detection light beam 73 near
slit 71 both in the main-scanning plane and the sub-
scanning plane. Reference numeral 75 denotes a mirror
(to be referred to as "BD mirror" hereinafter) for
15 reflecting the synchronism detection light beams 73 to
BD sensor 72, which will be described hereinafter, in
order to regulate the timing of scanning the surface of
the photosensitive drum 8 in the main-scanning
direction. Reference numeral 71 denotes a slit
20 arranged at a position equivalent to the surface of the
photosensitive drum 8. Reference numeral 74 denotes a
beam detector lens (BD lens) operating as focussing
lens for making the BD mirror 75 and the BD sensor 72
show a conjugated relationship and correcting the
25 inclination of the BD mirror 75. Reference numeral 72
denotes a synchronism detection means comprising the BD
sensor (photosensor). The synchronism detection means

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72 of this embodiment is used to control the timing of scanning of each of the plurality of light beams emitted from the plurality of light emitting sections in the main-scanning direction at or near the center of the scanning width on the surface of the photosensitive drum 8. In other words, if the plurality of light beams have respective wavelengths that are different from each other in this embodiment, the timing of starting a scanning operation of each light beam is so controlled that the centers of the scanning areas of the plurality of light beams agree with each other on the surface to be scanned.

In this embodiment, a pair of divergent light beams (only one of them is shown in FIG. 5) optically modulated and emitted from the multi-semiconductor laser 1 as a function of image information applied to it are substantially collimated by the collimator lens 2 and restricted by the diaphragm 3 for the quantity of light before entering the cylindrical lens 4. The two substantially collimated light beams entering the cylindrical lens 4 then leave the lens without being modified in the main-scanning plane but converged in the sub-scanning plane to produce respective focussed linear images (running along main-scanning direction) on the deflection plane 5a1 of the optical deflector (polygon mirror) 5. The two light beams deflected by the deflection plane 5a1 of the optical deflector 5 are

then focussed as so many spots of light on the surface of the photosensitive drum 8 by way of the toric lens 61 and the refraction optical element 62 so that they scan the surface of the photosensitive drum 8 at a constant rate in the direction (main-scanning direction) as indicated by arrow 8a as the optical deflector 5 is rotated in the sense of arrow 5a. As a result, an image is recorded on the surface of the photosensitive drum 8, which is a recording medium.

At the same time, the two synchronism detection light beams 73 reflected and deflected by the polygon mirror 5 of this embodiment are led to the BD sensor 72 by way of the synchronism detecting optical element 7, the BD mirror 75, the slit 71 and the BD lens 74.

Then, the two BD signals (synchronizing signals) for the main-scanning direction obtained by detecting the output signal of the BD sensor 72 are used to control the timing of scanning (synchronizing timing) in the main-scanning direction at or near the center of the scanning width in the main-scanning direction on the surface of the photosensitive drum 8.

As pointed out above, the surfaces of the single anamorphic lens 7 made of a plastic material and formed by injection molding is arranged substantially orthogonally relative to the synchronism detection light beams 73 in this embodiment. As a result, if, for instance, the wavelength of the light source of the

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scanning optical element 6 as shown in FIG. 6. As a result, the variations in the magnification can be allocated to the starting side and the terminating side of image drawing to consequently reduce the extent of jittering to about a half of that of known comparable apparatus.

Therefore with the embodiment where the timing of scanning is controlled in the main-scanning direction at or near the center of the scanning width in the main-scanning direction on the surface of the photosensitive drum 8 and the surfaces of the single anamorphic lens 7 are arranged substantially orthogonally relative to the synchronism detection light beams 73, the jittering phenomenon of the multibeam scanning optical apparatus attributable to variations in the wavelength (initial wavelength) and those in the magnification due to environmental changes can be effectively suppressed even an inexpensive plastic lens formed by injection molding and not corrected for chromatic aberration of magnification is used for the scanning optical element.

Note that the scanning optical element of this embodiment comprises a refraction optical element and a diffraction optical element, the advantages of the first embodiment can be realized by using a scanning optical element comprising only a refraction optical element.

[Embodiment 2]

FIG. 7 is a schematic cross sectional view of a principal portion of the second embodiment of multibeam scanning optical apparatus according to the invention
5 taken along the main-scanning direction thereof.

In FIG. 7, reference numerals 11, 12, 13 and 14 denote respective scanning optical apparatus and reference numerals 21, 22, 23 and 24 denote respective photosensitive drums operating as so many image
10 carriers, whereas reference numerals 31, 32, 33 and 34 denote respective developing units and reference numeral 41 denotes a conveyor belt.

This embodiment of color image forming apparatus comprises a total of four scanning optical apparatus
15 (11, 12, 13, 14) arranged for the four colors of C (cyan), M (magenta), Y (yellow) and B (black) and is adapted to record respective image signals (image information) on the corresponding photosensitive drums 21, 22, 23 and 24 in parallel and carry out a color
20 image printing operation at high speed.

As pointed out above, the color image forming apparatus of this embodiment is adapted to form latent images on the corresponding surfaces of the respective photosensitive drums 21, 22, 23 and 24 by means of
25 respective light beams emitted from the four scanning optical apparatus 11, 12, 13 and 14 according to respective modulation signals. More specifically,

latent images of C (cyan), M (magenta), Y (yellow) and B (black) are formed on the corresponding surfaces of the respective photosensitive drums 21, 22, 23 and 24 and then transferred on a recording medium in a multiplexing fashion to produce a single full color image.

Thus, a color image can be printed at high speed as if a monochromatic image. However, since the four colors do not share a single scanning optical element in this embodiment, they can show variations in terms of scanning position (registration) to consequently produce a relative deviation of registration among different colors and degrade the produced image.

Sub 027 To avoid this problem, in this embodiment of tandem type color image forming apparatus comprising a plurality of scanning optical apparatus, the timing of scanning of each of the scanning optical apparatus is controlled on the surface of the corresponding photosensitive drum at or near the center of the scanning width in the main-scanning direction in a manner as described above by referring to the first embodiment. In other words, the photodetector (BD) sensor and the center of the scanning width in the main-scanning direction on the surface to be scanned are optically held equivalent. To realize this, the surfaces of the synchronism detecting optical element (anamorphic lens) made of a plastic material and formed

detection timing does not shift regardless of variations in the wavelength and those in the refractive index due to environmental changes so that the focussing positions of the image area are made to vary symmetrically relative to the optical axis of the scanning optical element as shown in FIG. 8. As a result, the variations in the magnification can be allocated to the starting side and the terminating side of image drawing to consequently reduce the extent of relative deviation of registration among different colors to about a half of that of known comparable apparatus. Note that while FIG. 8 shows color deviation between B (black) and C (cyan), similar results are obtained for other colors.

Therefore with the embodiment of scanning optical apparatus used for a tandem type color image forming apparatus where the timing of scanning is controlled in the main-scanning direction at or near the center of the scanning width in the main-scanning direction on the surface of the photosensitive drum and the surfaces of the single anamorphic lens are arranged substantially orthogonally relative to the synchronism detection light beams in each of the scanning optical apparatus, the extent of relative deviation of registration among different colors attributable to variations in the wavelength and those in the magnification due to environmental changes can be

effectively suppressed even an inexpensive plastic lens formed by injection molding and not corrected for chromatic aberration of magnification is used for the scanning optical element.

5 Note that the scanning optical apparatus of this embodiment of color image forming apparatus may be replaced by the multibeam scanning optical apparatus as described above by referring to the first embodiment. Then, the obtained color image forming apparatus can be
10 operated for an enhanced degree of high speed operation and high definition.

[Embodiment 3]

FIG. 9 is a schematic cross sectional view of a principal portion of the third embodiment of the
15 invention, which is also a multibeam scanning optical apparatus, taken along the main-scanning direction thereof. In FIG. 9, the components same as those of FIG. 5 are denoted respectively by the same reference symbols.

20 This embodiment differs from the first embodiment only in that the synchronism detecting optical element is formed integrally with the refraction optical element of the scanning optical element by injection molding using a plastic material. Otherwise, this
25 embodiment is substantially identical with the first embodiment in terms of configuration and optical effect. Thus, this embodiment operates like the first

embodiment.

Referring to FIG. 9, reference numeral 17 denotes the integral type plastic optical element formed by injection molding and operating as synchronism
5 detecting optical element which is an anamorphic lens and also as refraction optical element which is a toric lens. With this arrangement, any spatial interference of the synchronism detecting optical element and the refraction optical element is eliminated to make it
10 possible to detect the scanning position at a position close to the image area and reduce the jittering phenomenon.

Note that, while the synchronism detecting optical element and the refraction optical element are
15 integrally formed in this embodiment, the synchronism detecting optical element and the second optical element which is the cylindrical lens may alternatively formed as integral components by injection molding, using plastic as raw material. Still alternatively,
20 the synchronism detecting optical element, the refraction optical element and the cylindrical lens may be integrally formed by injection molding, using plastic as raw material. This embodiment may be applied to a color image forming apparatus as described
25 above by referring to the second embodiment.